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DEVELOPMENT PROGRAM FOR 30MM ALUMINUM ALLOY CARTRIDGE CASE FOR CLOSE-AIR-SUPPORT GUN SYSTEM

HARVEY ALUMINUM INCORPORATED

TECHNICAL REPORT AFATL-TR-71-23

FEBRUARY 1971

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EGLIN AIR FORCE BASE, FLORIDA

1971

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Development Program For 30MM Aluminum Alloy Cartridge Case For Close-Air-Support Gun System

H.F. Boekhoff

FOREWORD

This is the final report of a program to design, develop, fabricate and test a 30mm aluminum alloy cartridge case for the Close-Air-Support Gun System. The program was conducted by Harvey Aluminum Incorporated, 19200 South Western Avenue, Torrance, California, under Contract F08635-69-C-0221 with the Air Force Armament Laboratory, Eglin Air Force Base, Florida, during the period from 19 July 1969 to 31 December 1970. The program monitor for the Armament Laboratory was Mr. David G. Uhrig (DLDG). The Project Number is 670A, Task 10, and Work Unit 011.

The program was managed for the contractor by Mr. Harry F. Boekhoff. Significant assistance was afforded by Mr. G. A. Moudry and Dr. R. W. Hilton, who are co-inventors of the aluminum alloy and the impact extrusion process used to produce the 30mm cartridge cases. The contractor's report number is HA-2537.

This technical report has been reviewed and is approved.

Charles Petrides
CHARLES PETRIDES
Chief, Advanced Development Division

ABSTRACT

This is the final report of a program to develop a 30mm aluminum alloy cartridge case in support of the Close-Air-Support Gun System Program. The case was designed and developed to utilize a special cartridge case alloy fabricated by the impact extrusion process. A total of 112 cases were successfully test-fired. Eighty-one used the M36A1E1 primer with ignition booster; thirty-one used the XM115 primer without booster. The M36A1E1 primer produced a barrel action time of 9.9 msec, and the XM115 primer produced a barrel action time averaging 125.0 msec. Propellant CIL 1379C produced the most satisfactory ballistic function with the lowest chamber pressure. A contractor-developed projectile crimp sustained a bullet-pull of 1000 pounds (minimum) and did not cause mouth erosion.

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INTRODUCTION

The objective of this program was to develop a satisfactory 30mm aluminum alloy cartridge case for the Close-Air-Support Gun System. This 30mm A-X aluminum alloy cartridge case is required to satisfactorily withstand the ballistic forces necessary to accelerate a 5000-grain projectile to a muzzle velocity of 3500 fps with a maximum chamber pressure of 60,000 psi. The case must also be capable of a 1000-lb (minimum) bullet-pull projectile crimp that will not cause neck erosion or splits.

Past development of aluminum cartridge cases has exhibited problems such as case erosion, case fracture, rim shearing and primer area defects. A principal factor in eliminating these defects was the use of the contractor's special cartridge case aluminum alloy in conjunction with impact extrusion manufacturing processes for the 30mm aluminum alloy cartridge case.

During the course of initial and subsequent contract modifications, a total of 112 cases were satisfactorily test-fired under fully instrumented conditions. Test results and the structurally sound condition of the test-fired cases substantiated that past problems, associated with development of aluminum cartridge cases, could be solved. Specifically, the 30mm aluminum alloy cartridge case developed under this contract meets the specified ballistic and crimp requirements.

SECTION II

DESIGN AND MANUFACTURING DEVELOPMENT OF 30MM ALUMINUM CARTRIDGE CASE

1. GENERAL REQUIREMENTS

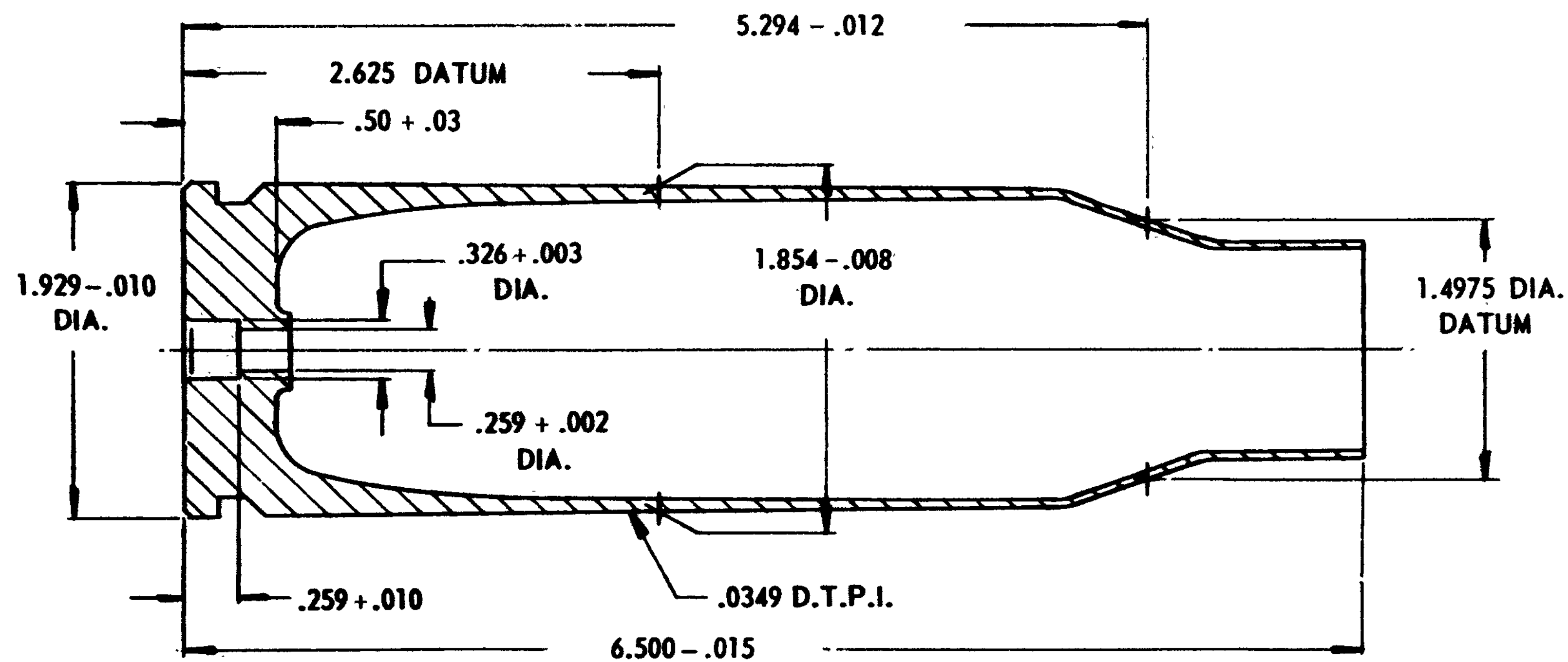
Contract work was initiated with a design study program to establish a 30mm aluminum alloy cartridge case design that would satisfactorily withstand the ballistic forces required to accelerate a 5000-grain projectile to 3500 fps muzzle velocity with a maximum chamber pressure of 60,000 psi. The cartridge case projectile crimp bullet-pull requirement was subsequently established in Contract Modification P0002, dated 20 August 1970.

A meeting was held with Eglin AFB and contractor technical representatives on 10 September 1969 to discuss the program. Primary design considerations resolved at this meeting were:

- No restraints were to be imposed; however, it was preferred that the case, when assembled with the 30mm projectile, not exceed 10-1/2 inches in length.
- The cartridge case should have a cavity volume of approximately 10 cubic inches of usable propellant space.
- The primer would be the M36A1E1 percussion-type.
- An ignition booster would probably be required.

Initially, the most important design factor in establishing the cartridge case design was provision for sufficient case volume for the propellant to be used while maintaining a geometry which provided the optimum relationship of producibility, extractability, gun geometry and packaging density. Another important factor (though not formally stated) was that the cartridge case be capable of being hydraulically crimped in a manner typical of current government loading practice.

In accordance with these objectives, the 30mm aluminum cartridge case was designed as shown in Figure 1 and as described in the stress analysis included in the appendix. Total cartridge case cavity volume is 11.6 cubic inches which would provide approximately 10 cubic inches for propellant, assuming the projectile boattail and adjacent area would occupy 1.6 cubic inches.



NOTE:

1. CARTRIDGE CASE CAVITY
   VOLUME = 11.65 IN.^{3}

Figure 1. Initial 30mm Aluminum Alloy Cartridge Case Design

Overall length of the case is 6-1/2 inches with a neck length of approximately 0.8-inch. This cartridge case design did not change throughout the program except for the primer pocket depth and diameter which were modified for test firing with the XM115 primer.

A 30mm aluminum cartridge case design was prepared which was typical of that shown in Figure 1 except the overall length was 6.30 inches (0.200-inch shorter). However, no action was taken on the shorter case, since the selected design appeared to be optimum in case volume for initial development.

The cartridge case material chosen for case development is of the Al-Cu-Mg-Si-type aluminum alloy, as defined in U.S. Patent No. 3,498,221, dated 3 March 1970. The basic impact extrusion manufacturing process is shown in Figure 2.

2. BACKGROUND

A meeting was held at Frankford Arsenal on 19 May 1966. At this meeting, selected personnel from the United States aluminum industry were briefed by Frankford Arsenal personnel on the advantages of a satisfactory aluminum cartridge case for small arms and the problems which had been encountered in the past in developing a satisfactory production product. After this meeting, contractor engineering personnel conducted a review of past efforts and material used in development programs for the 7.62mm and other small arms cartridge cases. A summation of this review follows:

The work previously conducted by Frankford Arsenal and others was based on the use of aluminum alloy 7075-T6, and the approach to production of the case followed the usual cup-and-draw method customarily used for standard brass cartridge cases. The contractor's position was that 7075 alloy was not basically suited for this type of operation, and because of the preponderance of grain boundary precipitate that was usually evident after rolling and subsequently drawing, concentrated areas of weakness could be obtained at random in a case which might lead to failure of the case during firing. This problem had persisted in Frankford Arsenal's development program and was referred to as "burn through." The 7075 alloy is also noted for high susceptibility to insidious stress corrosion.

It was also thought that the unique requirements of a material were such that a particular combination of metallurgical properties were required to obtain the performance attributes required for cartridge case service. The brass cartridge case which has been the accepted standard is produced by cold working, and through years of experience, the process has resulted in the attainment of a case which is work-hardened to a fully hard condition at

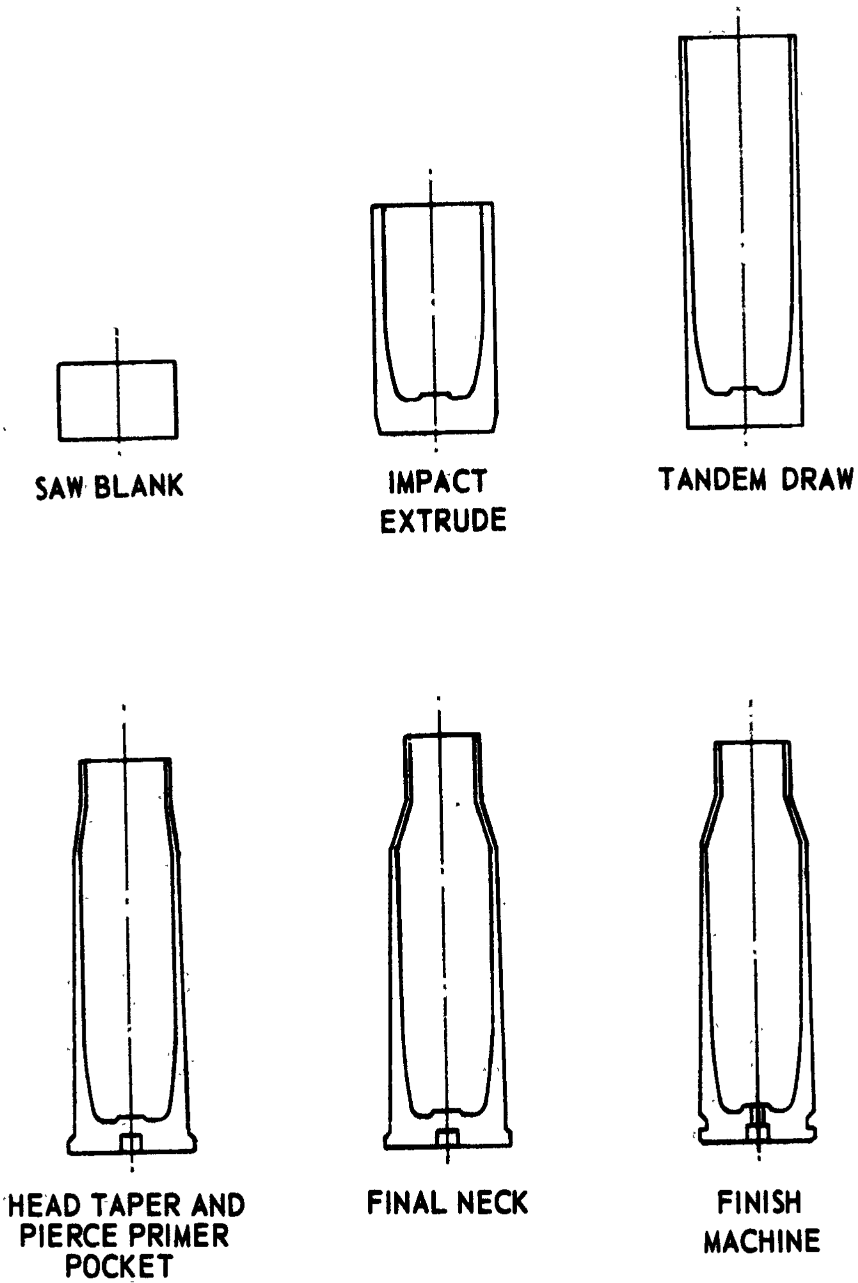


Figure 2. Basic Impact Extrusion Manufacturing Process

the head and gradually tapers off to a semi-annealed condition at the mouth. Maximum mechanical properties and hardness were believed a requisite to withstand the firing of the charge at the head area of the case, and higher ductility was needed at the mouth to prevent splitting during firing and to allow crimping in the projectile during loading.

The contractor was of the opinion that the aluminum alloy to be used for new cartridge case designs tailored to aluminum, or when used as a replacement for brass, should have: (a) good working characteristics to allow ease of fabrication; (b) a macrostructure that would not have residual lines of weaknesses at grain boundaries in the finished aluminum cartridge case; (c) a yield strength of 60,000 psi (minimum) to withstand the pressures developed during firing; and (d) a minimum ductility of 8-percent elongation in the final case to prevent fracture during firing and allow the case to yield to the weapon chamber wall and recover following firing to allow extraction of the spent cartridge. It was obvious that a heat-treatable alloy would be necessary, and one using the magnesium silicide-type with the addition of $CuAl_2$ for further strength was chosen.

Because aluminum alloys have alloying constituents that tend to segregate at grain boundaries, the use of sheet or plate, commonly used for brass, and previously used in aluminum alloy cup-and-draw development attempts, would be suspect because of grain flow patterns.

It was believed that drawn rod having a grain pattern in the direction of extrusion and drawing would provide the optimum macrostructure for this service. On fabrication of a cut slug from the rod and by utilization of unique impact extrusion methods, the grain flow would result in optimum strength of the material in the finished case.

During a previous aluminum cartridge case development, a difficulty that had been encountered with rapidly fired weapons was in extraction of the spent case. It had been stated that the characteristics of aluminum differed from those of brass to the extent that the case would seize in the chamber following firing, and ejection could result in failure at the rim. This was attributed to galling of the case in the chamber and weakness of the aluminum to withstand the force of the ejector.

It is believed that by providing a material and a fabrication method that would result in a smooth surface, and by further enhancing the surface of the case with a particular protective film having good lubricity, the problem of extraction could be avoided and thereby bypass the necessity of having the high hardness and strength which was deemed necessary in the rim area to assist extraction.

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3. MANUFACTURING DATA

The impact extrusion manufacturing process for the 30mm aluminum alloy cartridge case is described by the following basic metal-forming steps as shown in Figure 2:

- Receive aluminum rod drawn to size
- Saw slugs to length
- Anneal
- Lubricate
- Impact extrude
- Anneal
- Lubricate
- Tandem draw
- Trim
- Clean
- Heat treat
- Lubricate
- Head taper and pierce primer pocket
  *Flash anneal neck (also relubricate)
- Final neck to size
- Age
- Machine head
- Trim to length
- Final surface protective treatment (modified anodize)

Tool design and fabrication for development parts consisted of the following:

- Impact extrusion die
- Tandem draw die
- Head and taper die

*Quantity manufactured to date. Flash anneal was used to prevent neck reduction separation. With proper lubrication, this operation can possibly be omitted.

- Final neck die
- Turret lathe setup to machine head and flash hole
- Drill press setup to trim case to length.

The tools performed satisfactorily; however, minor tool design improvements, such as carbide wear surface inserts, would be beneficial for high production.

The final protective coating for this case is a modified anodic coating that does not conform to MIL-A-8625. Essentially, the anodize cleaning process is shortened, and the coating thickness is reduced to between 0.00015 and 0.0002-inch to achieve a smoother case finish.

In reference to the 30mm Close-Air-Support Gun design, past experience with the 20mm M61 Gun (which has an approximate 180-deg. bearing on the case rim extractor area as compared to an approximate 45-deg. bearing on the M39 Gun case rim extractor area) indicates the aluminum cases would function most satisfactorily with maximum bearing area possible on the extractor rim.

The primer pocket was pierced to size in the heading operation for cold work strength and performed well in test firing; however, there were occasional slight print dimension variances. In a production run, the primer pocket could be pierced slightly under size and then machined to print dimension. In a subsequent contract modification to test-fire the XM115 primer, primers pierced to size were machined to the XM115 primer dimensions and performed as satisfactorily as the primer pockets pierced to size.

SECTION III

30MM TEST GUN DATA, PROPELLANT DATA AND TEST PROCEDURE

The 30mm test barrel, with gain twist rifling, was fabricated by the Philco-Ford Corporation, Aeronutronics Division, to the following criteria:

Barrel length (origin of rifling to muzzle)	84 inches
Groove diameter	$1.235^{+.004}$ inch
Number of grooves	16
Groove width	$0.155^{+.006}$ inch
Land width	0.081/0.087 inch
Bore diameter	$1.1835^{+.0040}$ inch
Rifling Twist	$Y = KX^{N}$
	$dY/dX = \text{TAN } L$
	N = 1.50
	K = 0.010106
	Y = circumferential displacement
	X = inches into barrel

The 5000-grain inert test projectile has a rotating band diameter of $1.244^{-.004}$-inch with a width of 0.200-inch. All test projectiles performed well with no tumbling or rotating band separation. The muzzle end of the barrel is threaded to mount a projectile muzzle exit instrumentation electric coil, as shown in Figure 3. The chamber is threaded to mount on the origin of the rifling end of the barrel and is provided with a pressure port mount for either copper crusher or piezoelectric gage. The chamber pressure spring-actuated firing pin is mounted in a nylon housing which insulates it from the chamber. When the firing pin strikes the cartridge case primer, an electric circuit is completed that actuates the test firing recording instrumentation.

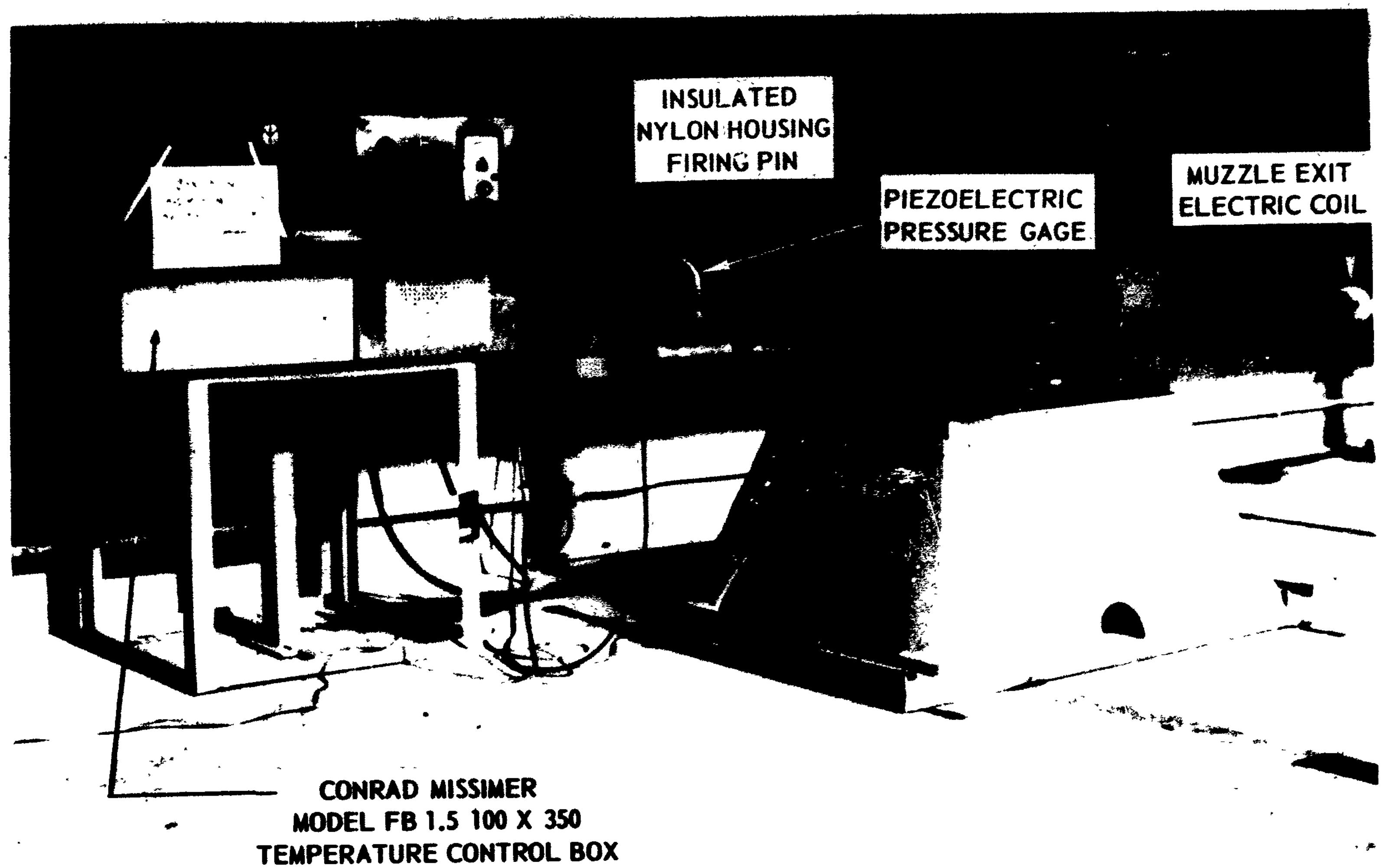


Figure 3. 30mm Test Gun

The instrumentation consists of a Tektronix Model 535 Oscilloscope-Polaroid camera with associated preamplifier and calibration units and a quartz-crystal piezoelectric pressure gage (the first 37 rounds fired used a copper crusher gage for chamber pressure), and Electronic Counters Inc. Model 6100 Ballistic Screens and Model 4000 Computing Chronograph for measuring projectile velocity. At the left of Figure 3 is a Conrad-Missimer Model FB 1.5 100 X 350 Temperature Control Box for conditioning hot (165°F) and cold (-60°F) test rounds. Projectile muzzle velocity was measured in accordance with AMCR 715-505, Vol. 8, Section 2. The two ballistic screens were placed 28 and 128 feet, respectively, from the barrel muzzle.

Each cartridge case test-fired for chamber pressure had a predrilled 1/8-inch diameter hole in the case to match the pressure port in the gun chamber. Care was taken to assure that there were no burrs in the case drilled hole.

The cartridge case propellant investigation involved contact and discussion with several manufacturers. The following companies supplied sample lots of propellant for tests as noted:

Olin Mathieson Corporation	X2899
DuPont Corporation	IMR 8261
Hercules Incorporated	6928-40
Canadian Industries Limited	1379C 1379A 1379B 1377C

Representatives from Hercules Incorporated and Canadian Industries Limited visited the contractor's plant to discuss propellant requirements, and as a result, Canadian Industries' 1379C appeared to be the most advanced for the particular ballistic requirements of the 30mm Gun System. This propellant is a single-base, single perforation tubular grain that utilizes a methylcentralite coating to control the burning characteristics. For a 5000-grain projectile, the web is 0.030-inch; the flame temperature is 2700°K, and the loading density is up to 0.033 lb/inch^3.

This propellant was chosen for initial testing and proved to be very satisfactory for the particular ballistic requirements of the 30mm aluminum cartridge case when ignited with a booster of approximately 1.3 grams FFFG black powder. The Hercules Incorporated and Olin Mathieson Corporation propellants were also tested as described in Section V of this report. The DuPont Corporation IMR 8261 propellant was not tested because it was similar in grain size to Hercules 6928-40 and Olin-Mathieson's X2899 propellants. All propellants tested, other than 1379C, produced chamber pressures that were too high in relation to projectile velocity.

SECTION IV

PROJECTILE CRIMP-BULLET PULL DEVELOPMENT

Initial crimp grooves in the first 5000-grain test projectiles were unsatisfactory in that the 0.005-inch radii on the crimp groove contributed to slight cartridge case mouth erosion (inasmuch as erosion did not occur in uncrimped cases). Furthermore, the cartridge cases were crimped with a standard pipe cutter tool equipped with projectile crimp groove rollers. In a later modification, a hydraulic-type of crimper was designed and fabricated by the contractor for the operation. Though similar to those used in government ammunition loading plants for pressure-crimping plastic rings on 20mm brass cases, the modified crimper is mounted on a 15-ton Dennison hydraulic press but uses mechanical pressure on the plastic (urethane) crimp ring of the 30mm aluminum alloy cases.

A load cell (Baldwin-Lima-Hamilton 60,000-pound, Type U-1C) was used to calibrate the dial indicator for the contractor press. The crimping psi pressure was determined by the 1.542-square-inch area of the urethane crimp disc pressurizing punch. The urethane crimp die could probably vary in area without adversely affecting the cartridge case crimp.

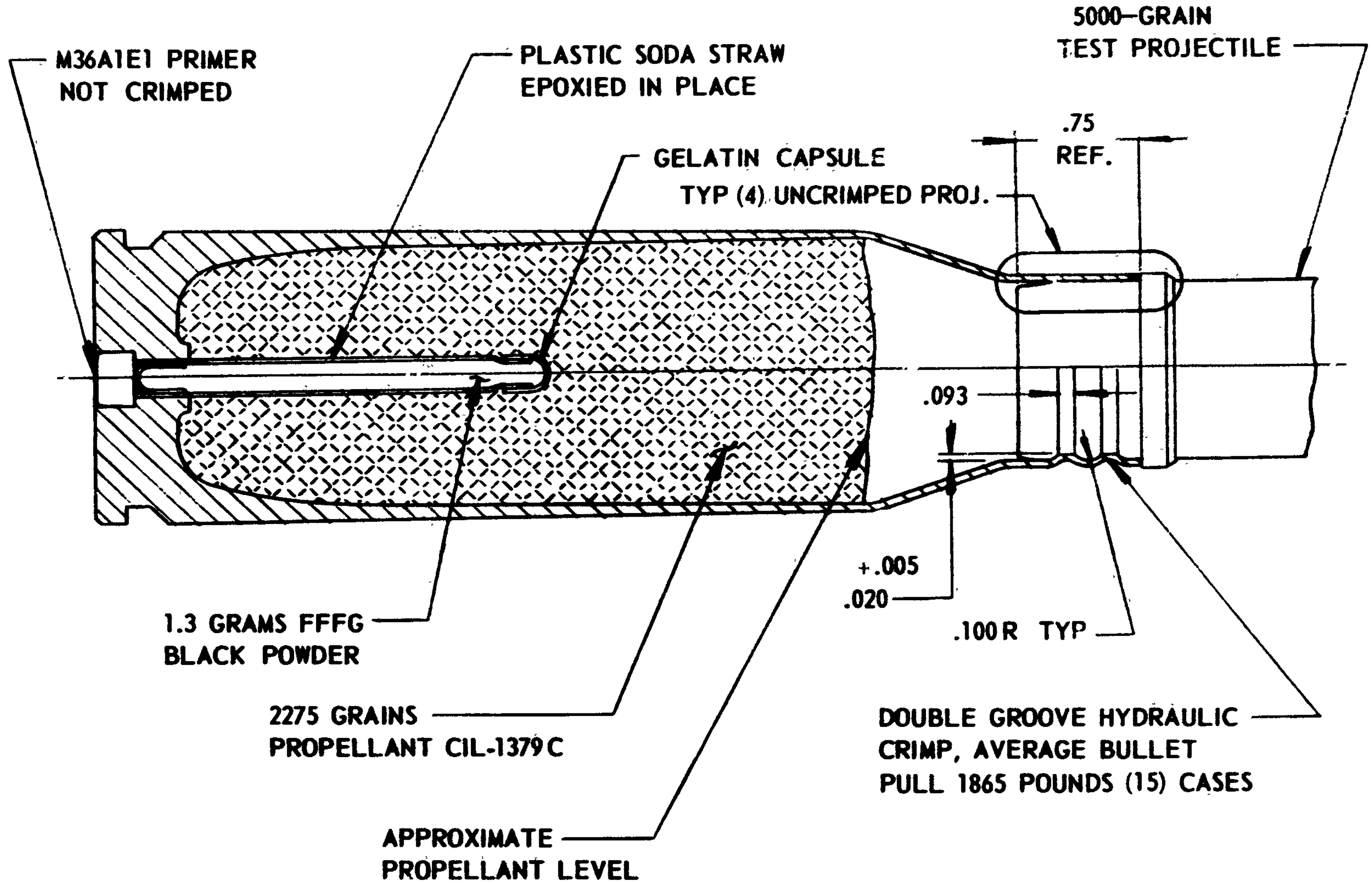
Work was also performed to develop a crimp that would have a minimum bullet pull of 1000 pounds and not cause case mouth erosion.

After a variety of projectile grooves were investigated, a double groove was established that performed satisfactorily. See Figure 4.

Fifteen 30mm aluminum alloy cartridge cases were then crimped with the double groove crimp. The detailed test data follows:

Cartridge Case	Press Dial Reading	Load Cell Calibration Conversion to psi	Bullet Pull (lb)
1	1350	22,213	1835

A hairline crack developed on the case lower crimp groove. The case cracked and separated at this location during the 1835-pound bullet pull. Investigation revealed a sharp edge on the projectile groove. The projectiles had been machined with a straight crimp area diameter for subsequent remachining with various crimp development grooves. The projectiles were screened for mismatched groove and diameter; however, the separated projectile had been overlooked.



USABLE CARTRIDGE CASE CAVITY V⁻LUME 10.8 IN.^{3}

Figure 4. Actual Loading Procedure

The press dial reading was reduced to 1300, and nine cases were crimped and satisfactorily bullet-pulled as follows:

Cartridge Case	Press Dial Reading	Load Cell Calibration Conversion to psi	Bullet Pull (lb)
2	1300	21,400	1825
3	↑	↑	1995
4			2155
5			1995
6			1950
7			1910
8			2000
9	↓	↓	1940
10	1300	21,400	1770

All cases were satisfactory and contained no cracks.

The press dial reading was then reduced to 1275, and five cases were crimped and bullet-pulled as follows:

Cartridge Case	Press Dial Reading	Load Cell Calibration Conversion to psi	Bullet Pull (lb)
11	1275	20,979	1705
12	↑	↑	1770
13			1670
14	↓	↓	1660
15	1275	20,979	1790

All cases were satisfactory and contained no cracks. Bullet-pull with all cases was 1/8 to 1/4-inch per minute on a metallurgical laboratory tensile-testing machine. The crimp used on cases 11 through 15 was also used on 31 cases that were test-fired as described in Section V. This bullet-pull development was performed on cases with flash-annealed neck as described in Section II. In the event that flash-anneal is omitted from the manufacturing process, a slight modification to the projectile crimp groove described may be necessary.

SECTION V

TEST FIRING DATA

Initial test firing of the 30mm aluminum alloy cartridge case was performed in March 1970. A total of 81 rounds were fired during March, April, and May 1970, and an additional 31 rounds were fired in November 1970.

The test firing program was initiated by using primed cases only to check firing pin intrusion into the M36A1E1 Primer. After firing pin adjustments, the next step of the firing program was to determine cartridge case structural reliability with related chamber pressure and propellant load.

1. FIRST TEST FIRE

Three rounds were loaded with reduced charge and test fired.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 1 with 0.145-inch diameter flash hole.

(2) Projectile

As shown in Figure 4 (not crimped).

(3) Primer

M36A1E1 (not crimped).

(4) Propellant

Canadian Industries Ltd. 1379C in quantities as follows:

Round 1: 1800 gr.

Round 2: 1800 gr.

Round 3: 2000 gr.

(5) Instrumentation

Chamber pressure copper crusher gage only at ambient temperature.

b. Results

Round	Chamber Pressure (psi)
1	30,200
2	30,200
3	39,700

All were very satisfactory structurally; however, propellant ignition appeared to be slow.

2. SECOND TEST FIRE

The next test consisted of eight rounds to check propellant ignition, projectile velocity and copper crusher chamber pressure with propellant CIL 1379C. A consumable cloth bag with one gram of black powder (FFFG) was used as a booster in seven of the eight rounds.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 1 with 0.145-inch diameter flash hole.

(2) Projectile

As shown in Figure 4 (not crimped).

(3) Primer

M36A1E1 (not crimped).

(4) Instrumentation

Copper crusher gage, chamber pressure and projectile velocity measuring screens (ref. Section III), temperature ambient.

b. Results

Round	Propellant Charge 1379C (gr)	Booster	Projectile Velocity (fps)	Chamber Pressure (psi)
4	2200	Yes	3468.7	50,200
5	2215.43	Yes	3517.6	52,700
6	2230.81	Yes	3541.8	53,800

Round	Propellant Charge 1379C (gr)	Booster	Projectile Velocity (fps)	Chamber Pressure (psi)
7	2246.29	Yes	3521.5	51,200
8	2200	No	Dud	Dud
	(primer fired, but was not sufficient to ignite propellant)			
9	2207.5	Yes	3507.8	51,200
10	2207.5	Yes	3508.4	50,700
11	2207.5	Yes	3449.0	45,400

Rounds 9 and 10 appeared ideal to meet chamber pressure and projectile velocity contract requirements. All cases were structurally sound.

3. THIRD TEST FIRE

This test consisted of three rounds using a tube-type consumable booster container and the same propellant and load used in the last three shots. In addition, the projectile was crimped on these rounds as noted.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 1 with the primer flash hole opened from the standard 0.145-.010-inch diameter to 0.250-inch diameter to accommodate a booster igniter tube (ref. Figure 4). Igniter tubes for tests described in this report were made from soda straws and gelatin capsules and worked satisfactorily as temporary measures.

(2) Projectile

As shown in Figure 4; crimped with pipe cutter tool as follows:

Round 12:	360-deg. crimp 0.007-inch deep
Round 13:	360-deg. crimp 0.008-inch deep
Round 14:	360-deg. crimp 0.009-inch deep

(3) Primer

M36A1E1 (not crimped).

(4) Igniter Tube Booster

Black powder (FFFG) 3/4-gram.

(5) Instrumentation

Same as previous 11 rounds.

b. Results

Round	Propellant Charge 1379C (gr)	Booster (gm BP)	Projectile Velocity (fps)	Chamber Pressure (psi)
12	2207.5	3/4	3441.6	47,000
13	2207.5	3/4	3443.7	48,500
14	2207.5	3/4	3439.0	47,500

All rounds were structurally sound; propellant velocities and chamber pressures were uniform, but projectile velocities were lower than expected. At first, this was attributed to the projectile crimp; however, continued testing indicated a possibility of slight variation in the performance continuity of CIL 1379C.

4. FOURTH TEST FIRE

a. Test Conditions

This test consisted of two rounds prepared the same as on the previous test, except the booster tube load was returned to one gram of black powder and the CIL propellant load was increased to 2215 grains. Also, the projectiles were not crimped.

b. Results

Round	Propellant Charge 1379C (gr)	Booster (gm BP)	Projectile Velocity (fps)	Chamber Pressure (psi)
15	2215.4	1	3503.8	50,700
16	2215.4	1	3467.1	53,800

All cases proved structurally sound. Primary results of rounds tested indicated the 30mm aluminum alloy cartridge case is structurally capable of sustaining the ballistic cycle to propel a 5000-grain projectile at 3500 fps.

5. FIFTH TEST FIRE

This test was performed to test another propellant, Hercules 6928-140. Four rounds were loaded and fired.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 1 (0.145-inch diameter flash hole).

(2) Projectile

As shown in Figure 4 (not crimped).

(3) Primer

M36A1E1 (not crimped)

(4) Instrumentation

Same as for Second Test Fire (para. 2).

b. Results

Round	Propellant Charge Hercules 6298-140 (gr)	Booster	Projectile Velocity (fps)	Chamber Pressure (psi)
17	1850	None	3287.1	54,800
18	1950	None	3441.2	61,400
19	2000	None	3476.4	61,900
20	2050	None	3526.8	68,900

All cases were structurally sound. The excessive chamber pressure (copper crusher gage) to achieve the 3526 fps projectile velocity served to temporarily omit this propellant from further testing.

6. SIXTH TEST FIRE

This test consisted of seven rounds to gain data on the CIL 1379C propellant with a one-gram igniter booster load in a soda straw container.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 4.

(2) Projectile

As shown in Figure 4 (not crimped).

(3) Primer

M36A1E1 (not crimped).

(4) Instrumentation

Same as second test fire (para. 2) at ambient temperature.

b. Results

Round Number	Projectile Charge CIL 1379C (gr)	Booster (gm BP)	Projectile Velocity (fps)	Chamber Pressure (psi)
21	2215.4	1	3460.6	50,700
22	2215.4	1	3459.7	49,600
23	2246.2	1	3473.8	51,200
24	2277	1	3497.2	50,700
25	2277	1	3514.0	51,200
26	2277	1	3518.4	51,700
27	2277	1	3502.8	51,700

All cases were structurally sound. Rounds 25, 26, and 27 were witnessed by representatives from Eglin Air Force Base. Rounds 24 through 27 displayed a very consistent uniformity in projectile velocity-chamber pressure.

7. SEVENTH TEST FIRE

This test was conducted for comparison of propellant performance.

a. Test Conditions

Two rounds were loaded and fired with Hercules 6928-140 propellant.

b. Results

Round	Propellant Charge Hercules 6928-140 (gr)	Booster	Projectile Velocity (fps)	Chamber Pressure (psi)
28	2025	None	3489.1	61,800
29	2025	None	3512.1	65,900

The cases were structurally sound; however, the chamber pressure was approximately 20 percent higher than the CIL propellants for equivalent projectile velocity.

8. EIGHTH TEST FIRE

This test consisted of four rounds of check Olin Mathieson propellant X2899.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 1 with 0.145-inch diameter flash hole.

(2) Projectile

As shown in Figure 4 (not crimped).

(3) Primer

M36A1E1 with disc to prevent fine granules of propellant from lodging behind primer anvil.

(4) Instrumentation

Same as for second test fire (para. 2).

Round	Projectile Charge Olin Mathieson X2899 (gr)	Booster	Projectile Velocity (fps)	Chamber Pressure (psi)
30	1950	None	—	47,000
31	2000	None	3174.8	46,400
32	2100	None	3312.6	55,800
33	2200	None	3433.3	66,400

The cartridge cases were sound; however, the excessive chamber pressure of Round 33, in relation to the projectile velocity, served to temporarily omit this propellant from further testing.

9. NINTH TEST FIRE

This test consisted of four rounds to check CIL propellant 1379C with 3/4-gram of black powder booster and crimped projectile.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 4.

(2) Projectile

As shown in Figure 4 (crimped with pipe-cutter tool).

(3) Primer

M36A1E1

(4) Instrumentation

Same as second test fire (para. 2) at ambient temperature.

b. Results

Round	Projectile Charge CIL 1379C (gr)	Crimp	Booster (gm BP)	Projectile Velocity (fps)	Chamber Pressure (psi)
34	2207.5	360-deg. 0.009-inch deep	3/4	3435.1	49,600
35	2207.5	360-deg. 0.009-inch deep	3/4	3471.2	47,500
36	2207.5	360-deg. 0.010-inch deep	3/4	3515.0	50,200
37	2207.5	360-deg. 0.010-inch deep	3/4	3483.0	49,600

All cases were sound except Round 37 wherein the neck separated at the 0.010-inch deep crimp. This indicated the 0.010-inch deep crimp, as emplaced with a pipe cutter-type of tool, to be marginal.

10. TENTH TEST FIRE

This test consisted of nine rounds conditioned for 12 hours at 125°F prior to firing.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 4.

(2) Projectile

As shown in Figure 4.

(3) Primer

M36A1E1 (not crimped).

(4) Instrumentation

Piezoelectric pressure trace and projectile barrel action time on Polaroid film.

b. Results

Round	Propellant Charge CIL 1379C (gr)	Booster Black Powder (gram)	Projectile Velocity (fps)	Chamber Pressure (psi)	Action Time (msec)
38	2277	1	3551.9	No trigger	
39	2277	1	3571.9	No trigger	
40	2277	1	3570.8	49,560	6.0
41	2277	1	3557.7	53,340	6.6
42	2277	1	3591.9	53,760	5.2
43	2277	1	3577.2	53,760	6.4
44	2277	1	3583.1	54,180	5.4
45	2277	1	3567.5	53,760	7.5
46	2277	1	3558.2	54,600	6.3

b. Results

All Cartridge cases were structurally sound.

11. ELEVENTH TEST FIRE

Ten rounds were conditioned for 12 hours at 72°F prior to firing.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 4.

(2) Projectile

As shown in Figure 4 (not crimped).

(3) Primer

M36A1E1 (not crimped).

(4) Booster Igniter Tube

Polyethylene soda straw as shown in Figure 4.

(5) Instrumentation

Piezoelectric pressure trace and projectile barrel action time on Polaroid film.

b. Results

Round	Propellant Charge CIL 1379C (gr)	Booster Black Powder (gram)	Projectile Velocity (fps)	Chamber Pressure (psi)	Action Time (msec)
47	2277	1	3507.0	51,240	7.0
48	2277	1	3553.1	54,600	6.6
49	2277	1	3544.4	53,760	6.9
50	2277	1	3546.6	52,500	—
51	2277	1	3544.1	54,180	7.0
52	2277	1	3560.7	55,440	6.8
53	2277	1	3542.2	54,600	6.9
54	2277	1	3561.4	55,440	7.1
55	2277	1	3523.2	53,760	7.7
56	2277	1	3524.1	52,920	8.0

All cartridge cases were structurally sound.

12. TWELFTH TEST FIRE

This test consisted of nine rounds conditioned at -60°F for 12 hours prior to firing.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 4.

(2) Projectile

As shown in Figure 4 (not crimped)

(3) Primer

M36A1E1 (not crimped).

(4) Booster Igniter Tube

Polyethylene soda straw as shown in Figure 4.

(5) Instrumentation

Piezoelectric pressure trace and projectile barrel action time on Polaroid film.

b. Results

Round	Propellant Charge CIL 1379C (gr)	Booster Black Powder (gram)	Projectile Velocity (fps)	Chamber Pressure (psi)	Action Time (msec)
57	2277	1	3483.8	51,240	–
58	2277	1	3465.9	49,560	14.2
59	2277	1	3464.6	49,140	13.0
60	2277	1	3480.8	49,560	11.0
61	2277	1	3477.5	50,400	13.4
62	2277	1	3476.6	49,560	10.4
63	2277	1	3496.2	50,400	11.5
64	2277	1	3483.1	50,400	11.0
65	2277	1	3486.1	50,400	14.4

All cartridge cases were structurally sound.

13. THIRTEENTH TEST FIRE

This test consisted of four rounds fired at ambient temperature with the black powder booster increased to 1.3 grams. Propellant was changed to 2275 grains.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 4.

(2) Projectile

As shown in Figure 4 (not crimped).

(3) Primer

M36A1E1 (not crimped).

(4) Booster Igniter Tube

Polyethylene soda straw as shown in Figure 4.

(5) Instrumentation

Piezoelectric pressure trace and projectile barrel action time on Polaroid film.

b. Results

Round	Propellant Charge CIL 1379C (gr)	Booster Black Powder (gram)	Projectile Velocity (fps)	Chamber Pressure (psi)	Action Time (msec)
66	2275	1.3	3501.0	–	–
67	2275	1.3	3500.9	47,191	–
68	2275	1.3	3519.2	50,562	9.0
69	2275	1.3	3525.8	50,562	9.9

All cases were structurally sound. Projectile action time for rounds 68 and 69 was unexpectedly long compared to barrel action time for tests noted in rounds 47 through 56 (para. 11, Eleventh Test Fire).

14. FOURTEENTH TEST FIRE

This test was witnessed by two representatives from Eglin Air Force Base. Seven rounds were loaded and test fired at ambient temperature.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 4.

(2) Projectile

As shown in Figure 4 and crimped in two places 0.008 and 0.009-inch deep with pipe-cutter tool.

(3) Primer

M36A1E1 (not crimped).

(4) Booster Igniter Tube

Polyethylene soda straw.

(5) Instrumentation

Piezoelectric pressure trace and projectile barrel action time on Polaroid film.

b. Results

Round	Propellant Charge CIL 1379C (gr)	Booster Black Powder (gram)	Projectile Velocity (fps)	Chamber Pressure (psi)	Action Time (msec)
70	2275	1.3	3472.2	45,900	7.0
71	2275	1.3	3504.6	47,600	9.0
72	2275	1.3	3489.4	47,600	10.0
73	2275	1.3	3528.7	51,000	9.0
74	2275	1.3	3519.7	51,000	8.5
75	2275	1.3	3485.0	48,500	8.5
76	2275	1.3	3524.2	51,000	9.0

All cases proved to be structurally sound except slight erosion occurred on the inside of the cartridge case neck crimp groove area. This erosion is due to the unnecessary sharp (0.005-inch radius) grooves on the projectile and the pipe cutter tool method of applying the crimp.

15. FIFTEENTH TEST FIRE

This final test in the firing program was arranged for Eglin Air Force Base project engineers who visisted the test site in May 1970 to review project progress. Five 30mm aluminum alloy cartridges were test fired at an bient temperature.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 4.

(2) Projectile

As shown in Figure 4 and crimped in two places 360-deg. by 0.008 to 0.009-inch deep using the pipe-cutter tool.

(3) Primer

M36A1E1 (not crimped).

(4) Booster Igniter Tube

Polyethylene soda straw.

(5) Instrumentation

Piezoelectric pressure trace and projectile barrel action time on Polaroid film.

b. Results

Round	Propellant Charge CIL 1379C (gr)	Booster Black Powder (gram)	Projectile Velocity (fps)	Chamber Pressure (psi)	Action Time (msec)
77	2262	2	3469.4	No trigger	
78	2262	2	3528.9	No trigger	(9.0)
79	2262	2	3516.4	48,876	7.0
80	2262	2	3462.3	43,820	8.0
81	2277	1.3	3493.5	47,191	9.0

All cases were structurally sound except slight erosion occurred again on the inside of the cartridge case crimp groove area. The two-gram black powder booster and 2262-grain CIL 1379C did not appear to be as uniform in velocity as the previous rounds fired with 2275-grain CIL 1379C and 1.3-gram black powder. Future rounds would probably perform best with 2275-grain CIL 1379C and 1.3 to 1.5 grams (FFFG) black powder. The 1 1/2-gram ignition booster load is based on results from a previous and related test firing program.

At this time, contract work was complete. Ten fired and unfired cases were shipped to the Eglin Air Force Base project engineer. Also, at this time, in concurrence with the project engineer, a recommendation was submitted to Eglin Air Force Base that additional contract work be performed to:

- Develop a suitable crimp that would not cause case mouth erosion but would sustain a specified bullet pull (results described in Section IV).

- Test fire a quantity of XM115 primers without a booster ignition using CIL 1379C Propellant.

16. TEST FIRE OF XM115 PRIMER

Upon receipt of contract modification authorization, a total of thirty-one 30mm aluminum alloy cartridge cases with primer pockets machined (larger)' to $0.370^{+.003}$-inch diameter by $0.272^{+.008}$-inch depth. These cases had a $0.145^{-0.010}$-inch flash hole diameter.

The 5000-grain test projectile had two crimp grooves as shown in Figure 4. All cartridge cases were crimped on the hydraulic crimper, as described in Section IV. All test shots were fully instrumented which was typical of rounds 38 through 81.

a. Test Conditions

(1) Cartridge Case

As shown in Figure 1 except machined for XM115 primer.

(2) Projectile

As shown in Figure 4.

(3) Primer

XM115 (not crimped).

(4) Round Temperature

Ambient.

b. Results

Round	Propellant Charge (gr)	Crimp (psi)	Projectile Velocity (fps)	Chamber Pressure (psi)	Action Time (msec)
1	2275	21,400	—	—	—
2	2275	21,400	3458	—	—
3	2275	21,400	3459	—	—
4	2275	21,400	3458	47,600	80.0
5	2275	21,400	3469	48,600	95.0
6	2275	21,400	3456	—	—
7	2275	21,400	3462	48,600	105.0
8	2275	21,400	3467	49,800	65.0
9	2275	21,400	3439	46,500	175.0
10	Lost in loading projectile				
11	2295	21,400	3465	—	—
12	2295	21,400	3467	—	—
13	2295	21,400	3485	48,800	110.0
14	2295	21,400	3438	45,100	160.0
15	2295	21,400	3467	48,800	105.0
16	2295	21,400	3464	44,600	100.0
17	2295	21,400	3460	44,750	155.0
18	2295	21,400	3449	44,750	115.0
19	2295	21,400	3464	46,800	140.0
20	2325	21,400	3489	46,800	160.0
21	2325	21,400	3501	48,900	120.0
22	2325	21,400	3486	48,900	130.0
23	2325	21,400	3500	48,400	120.0
24	2325	21,400	3498	49,500	140.0

Increasing the amount of propellant CIL 1379C to 2325 grains appears to be adequate for projectile velocity with the XM115 primer of 3500 fps.

a. Test Conditions

The next four rounds were loaded to 2375 grains of propellant CIL 1379C to investigate chamber pressure effect on the XM115 primer. Four additional rounds were loaded with 2475 grains of propellant CIL 1379C to investigate increased chamber pressure on XM115 primer. The latter four rounds (29 through 32) were soaked in a controlled temperature cold box for 15 hours at -60°F prior to firing.

b. Results

Round	Propellant Charge (gr)	Crimp (psi)	Propellant Velocity (psi)	Chamber Pressure (psi)	Action Time (msec)
25	2375	21,400	3547	51,000	160
26	2375	21,400	3557	—	—
27	2375	21,400	3534	51,000	155
28	2375	21,400	3539	—	—
29	2475	21,400	3604	51,500	175
30	2475	21,400	3600	53,100	175
31	2475	21,400	3615	53,100	150
32	2475	21,400	3621	—	—

All cartridge cases were structurally sound. All fired satisfactorily except the ballistic action time was excessively long. Rounds 4 through 28 averaged 125 milliseconds from the time the primer was struck until the projectile exited the barrel. The low action time was 65 milliseconds; the high action time was 175 milliseconds. The low action times on rounds 4, 5, and 8 were with the least propellant charge and lower projectile velocity. The ballistic action time for previous 30mm A-X aluminum cases, fired with the M36A1E1 primer and 1.3-gram black powder ignition booster at ambient temperature, averaged 9.9 milliseconds. The cartridge case-projectile crimp performed satisfactorily. No neck splits, mouth erosion, or primer pocket gas blow-by occurred in the cases. Two cases contained very slight mechanical marks attributed to the projectile exit. These cases were submitted to Eglin Air Force Base together with five contract requirement XM115 primer test-fired cases.

SECTION VI

CONCLUSIONS

In test firings completed to date, 30mm aluminum alloy cartridge cases with M36A1E primer and ignition booster assembly as shown in Figure 4 have proven to be very satisfactory in meeting the contract structural reliability and ballistic performance requirements. No case fracture, rim shear, or primer defects occurred.

The hydraulic crimp used on the last 31 (XM115 primer) rounds performed satisfactorily with no mouth erosion occurring.

The double projectile groove average bullet pull for 15 cases was 1865 pounds, as described in Section IV and shown in Figure 4. A single groove could probably be developed for a lower bullet pull if desired.

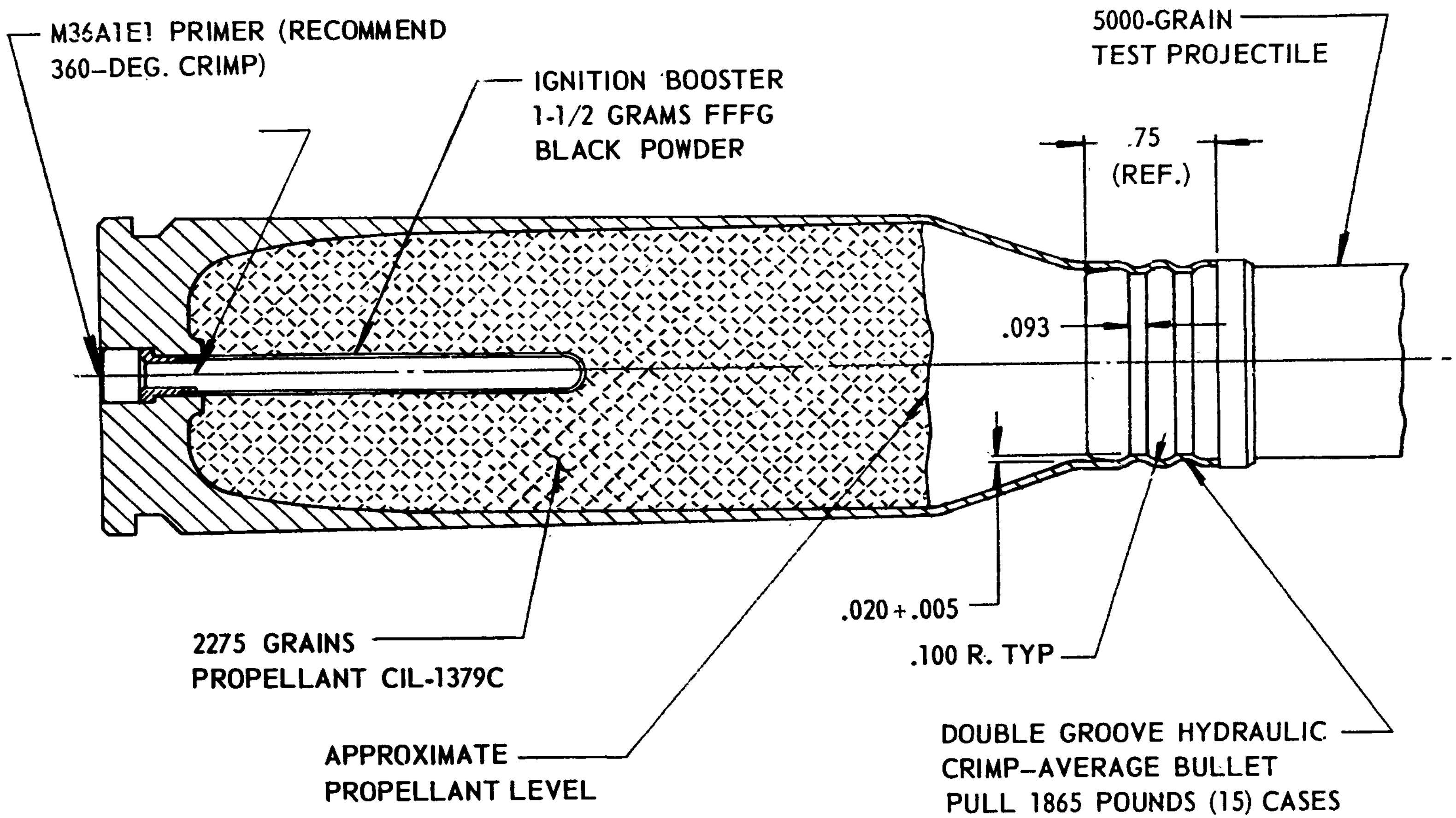
Although only a few 30mm aluminum cases have been satisfactorily crimped, test-fired and bullet-pulled, the test data substantiates that an aluminum cartridge case-projectile crimp, with a minimum bullet pull of 1000 pounds free of any deleterious mouth erosion, is feasible.

1. XM115 PRIMER

This primer will fire the 30mm aluminum cased round with 5000-grain projectile to 3500 fps with a CIL 1397C propellant charge of approximately 2325 grains. However, a major consideration is the slow action time of 125-millisecond average versus the 9 to 10-milliseconds for previous 30mm test rounds using the M36A1E1 primer and ignition booster. This 9 to 10-millisecond action time can probably be reduced to 5 milliseconds when the M36A1E1 primer anvil is supported by an aluminum plug which would be part of the ignition-booster assembly shown in Figure 5. In all previous M36A1E1 test firings (rounds 38 through 81, Section V), the M36 primer anvil rested over a 0.250-inch entrance hole for the plastic booster tube in place of the 0.145-inch recommended flash hole for the M36A1E1 primer.

2. CARTRIDGE CASE DESIGN

The 30mm aluminum alloy cartridge case design shown in Figure 1 was designed for optimum propellant use during initial development. Figure 4 shows the approximate propellant level when using CIL 1379C propellant. It appears the length of the cartridge case could be reduced from 6-1/2 inches to 6 inches (approximately) with a possible reduction in the propellant charge weight due to a smaller combustion chamber (higher loading density).



USABLE CARTRIDGE CASE CAVITY VOLUME 10.8 IN.^{3}
(WITH TEST PROJECTILE)

Figure 5. Recommended Loading Procedure

3. PROPELLANT

Canadian Industries Ltd. CIL 1379C Propellant appears to be most satisfactory for contract ballistic requirements.

4. MANUFACTURING METHOD

The basic impact extrusion manufacturing process, shown on Figure 2 for the 30mm aluminum alloy cartridge case, has proven to be a practical and reliable method of manufacture. This process, in conjunction with the contractor's aluminum cartridge case alloy, is readily adaptable to high production manufacturing techniques.

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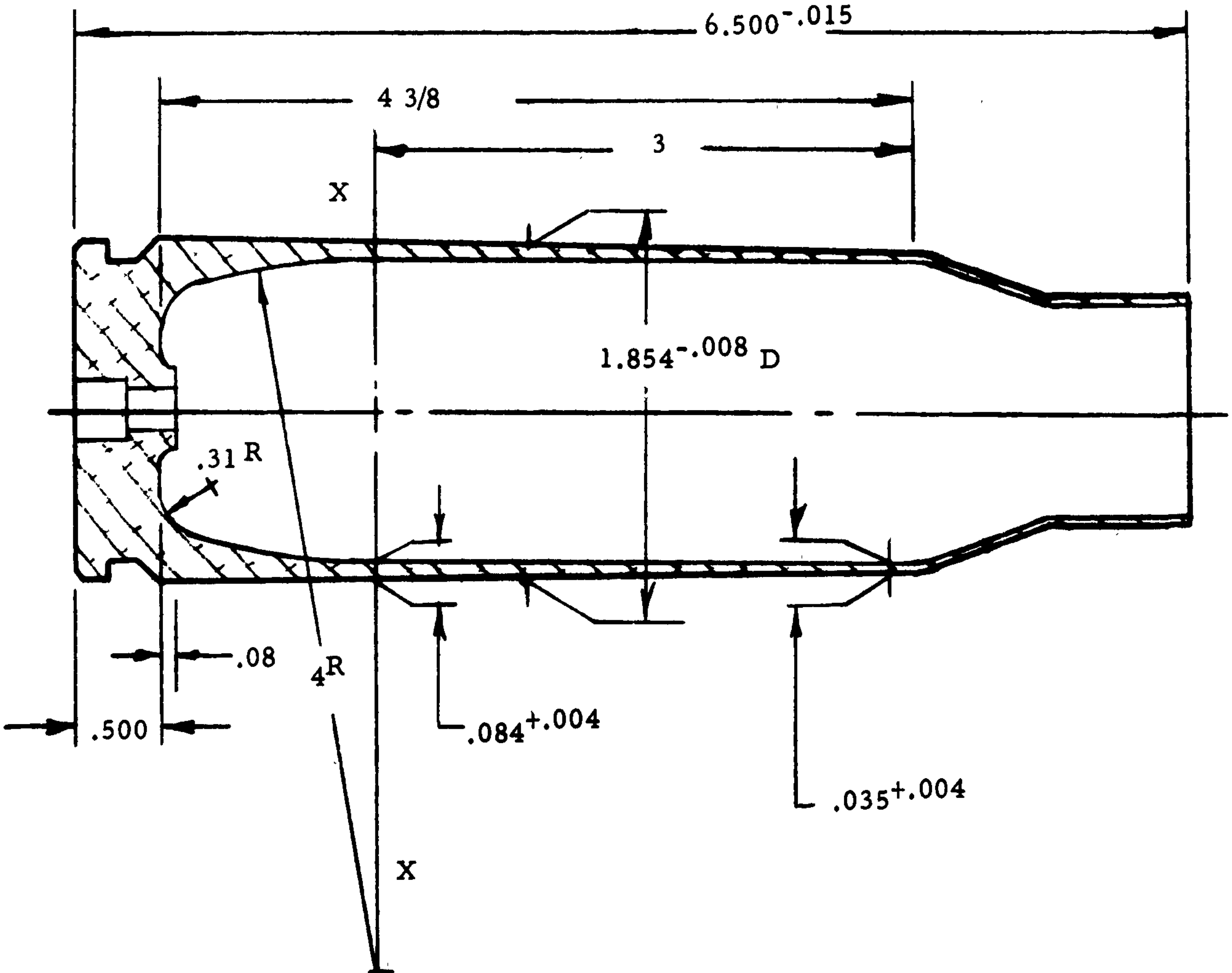
APPENDIX

STRESS ANALYSIS FOR
30MM ALUMINUM CARTRIDGE CASE
FOR CLOSE-AIR-SUPPORT GUN SYSTEM

$p = 60{,}000$ psi Maximum Pressure



Head Space = .005 - .006 in.

Aluminum Alloy per HA 65
F_{ty} = 60,000 psi

METHOD OF ANALYSIS

1. Calculation of unrestrained stress, deflection, and spring scale for 3-inch-length of body.

2. Calculation of unrestrained stress, deflection, and spring scale for 0.500-inch-thick base.

3. Calculation of the proportion each contributes to overall extension.

4. With 0.006-inch maximum head space, calculation of stresses in body, center of base, and outer rim of base. For stress at outer rim, calculation of deflection due to thinner base and prorate of the stress due to actual deflection.

5. Radial stresses in the case, which is restrained, are in the plastic range and cannot be calculated.

Deflection in 3-inch of Body

$$\text{O.D.} = 1.854^{-0.008}$$

$$\text{Average } t = \frac{0.084 + 0.035}{2} = \frac{0.119}{2} = 0.0595$$

$$\text{I.D. Average} = 1.854 - 0.119 = 1.735 \text{ in.}$$

$$A = \frac{\pi}{4}\left(\overline{1.854}^2 - \overline{1.735}^2\right) = 0.786(3.44 - 3.01)$$

$$= 0.786(0.43) = 0.338 \text{ in.}^2$$

$$E = \frac{\text{Stress}}{\text{Strain}} = \frac{P/A}{\delta/L} = \frac{PL}{\delta A}$$

$$\delta_1 = \frac{PL}{EA} \qquad E = 10 \times 10^6 \text{ psi}, \quad L = 3 \text{ in.}$$

$$p = 60{,}000 \text{ psi}$$

$$A_p = \frac{\pi}{4}\left(\overline{1.735}^2\right) = .786(3.01) = 2.36 \text{ in.}^2$$

$$P = pA_p = 60{,}000(2.36) = 141{,}700 \text{ lb}$$

$$\delta_1 = \frac{141{,}700(3)}{10 \times 10^6(0.338)} = \frac{0.425}{3.38} = 0.126 \text{ in.}$$

$$k_1 = \frac{P}{\delta_1} = \frac{141{,}700}{0.126} = 1.124 \times 10^6 \text{ lb/in.}$$

Stress in Body (unrestrained)

$$O.D. = 1.854 - 0.008 = 1.846 \text{ in. minimum}$$

$$t = 0.035 - 0.004 = 0.031 \text{ in. minimum}$$

$$I.D. = 1.846 - 0.062 = 1.784 \text{ in.}$$

$$A_p = \frac{\pi}{4}(1.784)^2 = 0.786(3.18) = 2.5 \text{ in.}^2$$

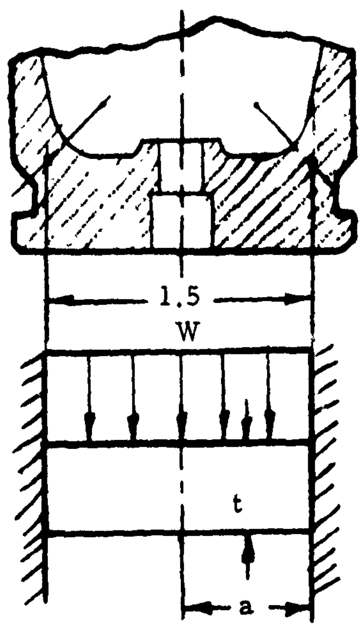
$$P = 60{,}000(2.5) = 150{,}000 \text{ lb}$$

$$A_T = \frac{\pi}{4}\left(\overline{1.846}^2 - \overline{1.784}^2\right) = 0.786(3.40 - 3.18)$$

$$= 0.786(0.22) = 0.173 \text{ in.}^2$$

$$\mathcal{f}_t = \frac{P}{A_T} = \frac{150{,}000}{0.173} = 867{,}000 \text{ psi (unrestrained)}$$

Assume solid base 0.50-inch thick(1)



$$p = 60{,}000 \text{ psi}$$

$$W = p\pi a^2$$

$$a^2 = (.75)^2 = 0.562$$

$$W = 60{,}000\,\pi(0.562)$$

$$= 106{,}000 \text{ lb}$$

$$t^2 = (0.5)^2 = 0.25$$

$$m = 3 \qquad m^2 = 9$$

$$E = 10 \times 10^6 \qquad m + 1 = 4$$

$$t^3 = 0.125 \qquad m^2 - 1 = 8$$

$$\text{(at center) } \mathcal{f}_t = \frac{3W(m+1)}{8\pi m t^2}$$

$$\mathcal{f}_t = \frac{(3)106{,}000(4)}{8\pi 3(.25)} = \frac{106{,}000}{1.57} = 67{,}500 \text{ psi (unrestrained)}$$

$$\delta_2 = \frac{3W(m^2-1)a^2}{16\pi E\, m^2 t^3} \quad \frac{(3)106{,}000(8)(0.562)}{16\pi 10 \times 10^6(9)(0.125)}$$

$$= \frac{0.238}{94.4} = 0.00252 \text{ in.}$$

$$k_2 = \frac{W}{\delta_2} = \frac{106{,}000}{0.00252} = 42 \times 10^6 \text{ lb/in.}$$

$$\text{Total Deflection} = 0.006\text{-in. head space}$$

$$\delta_{Body} = (.006)\frac{0.126}{(0.126 + 0.0025)} = (0.006)\frac{0.126}{(0.1285)}$$

$$= 0.0059 \text{ in.}$$

$$\delta_{Base} = 0.006 - 0.0059 = 0.0001 \text{ in.}$$

Stress in Body

$$f_t = 867{,}000\frac{0.0059}{0.126} = 44{,}000 \text{ psi}$$

F_{ty} = 60,000 psi (page 37)

$$\text{M.S.} = \frac{60{,}000}{44{,}000} - 1 = +0.36$$ +

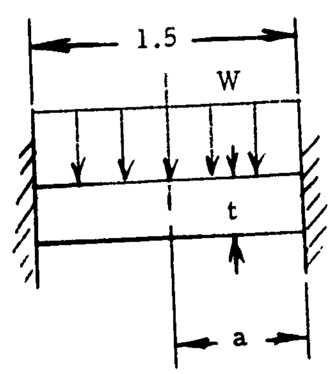
Stress in Base Center

$$f_t = 67{,}500\frac{0.0001}{0.00252}$$

$$= 2{,}670 \text{ psi}$$

$$\text{M.S.} = \frac{60{,}000}{2{,}670} - 1 = +21.5$$ excessive

Stress in Outer Rim of Base



$t = 0.30$ in. $\quad t^2 = 0.09$

$t^3 = 0.027$

$a = 0.75 \quad a^2 = 0.562$

$p = 60{,}000$ psi

$W = 106{,}000$ lb

$m = 3 \quad m^2 = 9$

$E = 10 \times 10^6 \quad m + 1 = 4 \quad m^2 - 1 = 8$

$$\text{(at edge) } f_t = \frac{3W}{4\pi t^2} \quad \text{Maximum}$$

$$f_t = \frac{(3)106{,}000}{4\pi(0.09)} = \frac{79{,}500}{0.283} = 281{,}000 \text{ psi (unrestrained)}$$

$$\delta_3 = \frac{3W(m^2-1)a^2}{16\pi E\, m^2 t^3} = \frac{(3)\,106{,}000\,(8)\,(0.562)}{16\pi\, 10 \times 10^6\,(9)\,(0.027}$$

$$= \frac{0.0596}{5.1} = 0.0117 \text{ in.}$$

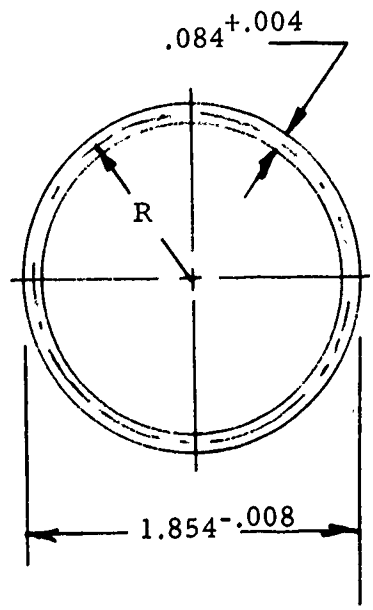
$$f_t = 281{,}000 \frac{0.0001}{0.0117} = 2400 \text{ psi}$$

$$F_{ty} = 60{,}000 \text{ psi}$$

$$\text{M. S.} = \frac{60{,}000}{2400} - 1 = +24.0$$

excessive

Check Stress and Radial Deflection at X-X
(Reference 1, page 268, Case 1)



$$f_1 = \frac{PR}{2t} \qquad f_2 = \frac{PR}{t}$$

$$\delta_{radial} = \frac{R}{E}(f_2 - v f_1)$$

$$p = 60{,}000 \text{ psi}$$

$$R = \frac{1.846}{2} - 0.084$$

$$= 0.923 - 0.084 = 0.839 \text{ in.}$$

$$t = 0.084 \text{ in. minimum}$$

$$E = 10 \times 10^6 \qquad v = 0.33$$

$$f_2 = \frac{PR}{t} = \frac{60{,}000(0.839)}{0.084} = 600{,}000 \text{ psi}$$

$$f_1 = \frac{600{,}000}{2} = 300{,}000 \text{ psi}$$

$$\delta_R = \frac{0.839}{10 \times 10^6}\left(600{,}000 - (0.33)300{,}000\right)$$

$$= 0.0839(0.600 - 0.100) = 0.0420 \text{ in.}$$

must be restrained

Calculated Wall Thickness That Will Not Yield

Neglect longitudinal stress

$$F_{ty} = \frac{pR}{t} = 60{,}000$$

$$p = 60{,}000 \text{ psi}$$

$$R = 0.923 - \frac{t}{2}$$

$$60{,}000 = \frac{60{,}000(0.923 - \frac{t}{2})}{t}$$

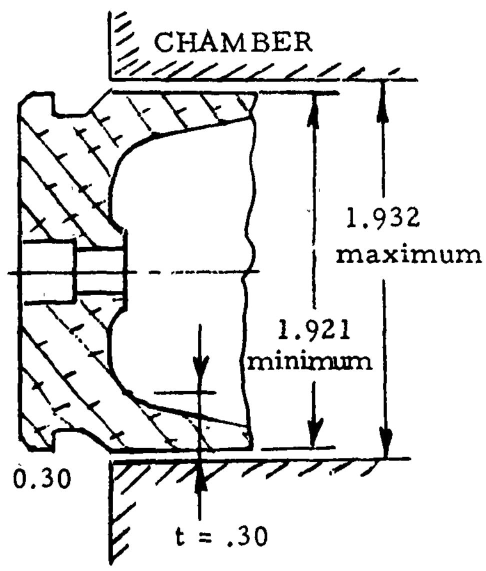
$$t = 0.923 - 0.5\,t$$

$$t = \frac{0.923}{1.50} = 0.615 \text{ in.}$$

Therefore: All of case will expand to chamber and will be restrained.

SECOND METHOD OF ANALYSIS

Assume the outside diameter of the base expands to the I. D. of the chamber before base stops deflecting.



Neglect axial deflection

$$\sigma_t = \frac{pR}{t}$$

$$\delta_r = \frac{R}{E}\left(\sigma_t\right)$$

$$= \frac{R}{E} \times \frac{pR}{t} = \frac{pR^2}{Et}$$

(Reference 1, page 268, Case 1)

$$R = 0.921 - 0.150 = 0.771 \text{ in.}$$

$$R^2 = 0.595 \qquad E = 10 \times 10^6 \qquad t = 0.30$$

$$\delta_R = \frac{0.003 + 0.008}{2} = 0.0055$$

$$p = \frac{\delta_R E t}{R^2} = \frac{(0.0055)\,10 \times 10^6 (0.3)}{0.595}$$

$$= \frac{55{,}000}{1.99} = 27{,}600 \text{ psi}$$

Use this pressure in calculating the stress in the base.

$$f_t = 67{,}500 \text{ at } 60{,}000 \text{ psi} \qquad \text{(page 40)}$$

$$\text{Effective } p = 27{,}600 \text{ psi} \qquad \text{(page 42)}$$

$$\text{Actual } f_t = 67{,}500 \frac{27{,}600}{60{,}000}$$

$$= 31{,}100 \text{ psi}$$

$$F_{ty} = 60{,}000 \text{ psi}$$

$$\text{M.S.} = \frac{60{,}000}{31{,}100} - 1 = +0.93 \longleftarrow \text{adequate}$$

<u>Recovery of Case</u>

$$\text{Maximum } T = 200^{\circ} \text{ F}$$

$$F_{ty} = 55{,}000 \text{ psi}$$

$$\delta = \frac{R}{E}(S_2) \qquad \text{Use } S_2 = 55{,}000 = \frac{pR}{t}$$

$$R = 0.927 - 0.042 = 0.885$$

$$\delta = \frac{0.885(55{,}000)}{10{,}000{,}000} = \frac{4.860}{1000} = 0.005 \text{ in. radially}$$

Therefore: Recovery of case is adequate.

CONCLUSIONS

All stresses found are well below stresses that could be produced by a 60,000-psi pressure. In these analyses, the cartridge case is fully restrained at all times after existing clearances have been taken up. Should the propellant be exposed to elevated temperatures, it is expected that the normal pressure would be exceeded. These pressures could exceed the 60,000-psi pressure by a considerable margin without adversely affecting the stresses as described. This is because the stresses are limited by the clearances and are not proportional to the pressures.

REFERENCE

1. Raymond J. Roark, Formulas for Stress and Strain, Third Edition, McGraw-Hill Book Company, Inc., N. Y., 1954, page 195, Case 6.

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13. ABSTRACT

This is the final report of a program to develop a 30mm aluminum alloy cartridge case in support of the Close-Air-Support Gun System Program. The case was designed and developed to utilize a special cartridge case alloy fabricated by the impact extrusion process. A total of 112 cases were successfully test-fired. Eighty-one used the M36A1E1 primer with ignition booster; thirty-one used the XM115 primer without booster. The M36A1E1 primer produced a barrel action time of 9.9 msec, and the XM115 primer produced a barrel action time averaging 125.0 msec. Propellant CIL 1379C produced the most satisfactory ballistic function with the lowest chamber pressure. A contractor-developed projectile crimp sustained a bullet-pull of 1000 pounds (minimum) and did not cause mouth erosion.

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